

# Evaluation of Concrete Quality Control Practices on Building Sites in North-Eastern Nigeria

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## ABSTRACT

The Evaluation of Concrete Quality Control Practices on building sites in North Eastern Nigeria was necessary considering the increasing reported cases of building failures. The study examined the current concrete production practices within the study area. A validated checklist backed-up by a questionnaire with reliability coefficient of 0.73 and 0.81 respectively were utilized to collate data on quality of concrete on building sites with value of 50 million naira and above. The data include selection of concrete ingredient, batching, mixing, transportation, placement, curing, equipment, personnel and temperature control. 100 questionnaires were distributed to site managers and concreting supervisors on building sites selected through non-probability sampling within the study area and 62% response was achieved. The data collected were analyzed using descriptive statistics and ANOVA at 95% confidence level. The findings revealed that most of the projects examined did not adhere to required procedure for concrete production such as testing of concrete materials and proper concreting process. The general performance of the project sites examined was fair with an average score of 'C'. Concrete production personnel and temperature control were the most severe problems observed with score of 'D'. The study recommended proper quality control and planning as well as utilizing skilled and knowledgeable personnel in concrete production.

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## Introduction

The construction industry is a very important sector of the economy. It plays a critical role in a nation's economy in the areas of the provision of job opportunities and infrastructural development. The rapid growth in a country's economy and population requires additional physical infrastructures; for instance residential and commercial buildings, agricultural and health facilities, among others to accommodate additional various components of the Gross National Product (GDP). The general trend of physical infrastructure in respect of buildings in Nigeria and indeed in the North East States in particular has been the use of concrete. Concrete is a major component of most of infrastructural facilities in the 21<sup>st</sup> century because of its versatility in service. Concrete is used more than any other man-made building material in the world. As of 2008, about 7.5 cubic kilometres of concrete were made each year and more than one cubic meter for every person on Earth [1]. Its importance in the modern society cannot be underestimated considering that it provides a firm support to high-rise buildings as well as the simple bungalow structures. These can be achieved through proper design and implementation of quality control measures during construction.

However, the performance of concrete in building in the recent times is giving concern to practitioners and other stakeholders in the construction industry in Nigeria [2].

[3] Opined that the quality of concrete is too difficult to control since it is made up from different heterogeneous materials. They also assert that it is even more difficult to maintain consistency of concrete quality while producing concrete from different batching plants and for different construction sites. [4] Nigerian Building and Road Research Institute, [NBRI] (2012) identified poor concreting as a major cause of collapse of buildings in Nigeria. Based on NBRI investigations, there has been no convincing evidence to suggest that structural design were lacking in most of situations.

According to [2] extensive research programmes are being conducted to investigate the causes of and factors responsible for concrete failures in buildings using different approaches such as review of literature reports of cases of failures, laboratory materials testing of concrete and concrete making aggregates, field evaluation using Non-Destructive Tests (NDT) procedures. To arrest this ugly trend, the costs of building failure are enormous both in terms of economic and most particularly loss of life.

Reference [2] asserts that the use of concrete test results which do not take cognizance of the real life site conditions, poor workability, poor workmanship, low quality cement, concrete construction at awkward times, use of concrete admixture, choosing contractors based on lowest bid, poor curing, poor aggregate-cement ratio, improper concrete compaction, poor concrete mixing practices, incompetent contractors and



personnel, poor working knowledge of concrete, etc. were factors responsible for building collapse in Nigeria. His study concludes that for the use of concrete in building construction to serve the intended purposes, the construction aggregate need to be well-studied and strict adherence to specifications must be emphasized. Serious awareness and retaining of construction workers are needed to tackle these challenges. The need for closer collaboration between structural engineers and architects is also emphasized to ensure that the quality control measures on the materials of construction and personnel are proficiently and tactfully used.

Quality control is one of the major concerns for project managers in the construction industry, in addition to time and cost. Unless a construction company can guarantee its client a quality product it cannot compete effectively in the modern construction market. Crucial to the delivery of such quality products is the quality of process that produces the product. The aim of quality control is to provide a quality product that is satisfactory to the investors, consumers, compliant with the statutory and industry standards, completion on schedule, within budget and so on. Therefore, quality control plays a critical role in such a way that it provides information for the project manager to develop contingency plans of preventing structural disaster. For instance, the rate of defects in construction projects could be minimized if the construction processes are closely monitored and examined throughout the construction process.

Quality is defined as "fitness for purpose" or compliance with specification [5, 6]. [7] Defined it as the totality of features required by a product or service to satisfy stipulated and implied needs. Similarly, International Standard Organisation, 8402-1986 standard defines quality as "the totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs". In a similar development, [8] identified quality as one of the three key elements for developing risk classification model for design and build projects. It therefore follows that quality is a significant factor that cannot be undermined in the construction of projects. Quality management and quality assurance on the other hand have been adopted to include all aspects of producing and accepting a construction project which meets all required quality standards [9]. He further asserts that quality management includes such activities as specification development, process control, product acceptance, laboratory and technician certification, training and communication. Consequently, [9] concluded that quality control, which is a part of the quality management process, is primarily concerned with process control function. The Standard Organization of Nigeria (SON) established through Act 56 in 1971 is the sole statutory body that is vested with the responsibility of standardizing and regulating the quality of all products in Nigeria including concrete and its materials.

Quality control as defined by Council of Registered Builders of Nigeria (CORBON) and the Nigeria Institute of Building (NIOB) [10] is monitoring specific project results and deliverables to determine if they comply with relevant quality standards and identifying ways to eliminate causes of unsatisfactory performance. It involves monitoring both the process and product, to determine if the project is meeting the quality standards and identifying ways to mitigate risk or eliminate causes of unsatisfactory results.

In these definitions and descriptions of quality, the authors consider quality from the view of products or services meeting up or satisfying defined needs. Therefore, application of quality control is a very important tool which can be used effectively for quality and productivity improvement for concrete production. The concrete producer needs to exercise strict control on the quality of all ingredients through rigorous testing, applies stringent controls on process parameters and monitors key properties of a fresh and hardened state. All these efforts result in providing uniform and assured quality of concrete.

Preliminary survey has shown that concreting process in most building sites is not given the desired attention. The resultant effect is manifestation of cracks and eventual building failure. This agrees with [4] that pointed out that incessant building failure is a result of poor concrete in Nigeria. Concreting process in the North-East region characterized by North-easterly winds require proper attention as weather condition has great effect on concrete quality if not properly controlled.

In view of the incessant building failure occasioned by poor concrete in Nigeria there is a great demand for enhancing performance of concrete in building and as such it becomes necessary to improve on production of quality concrete. This is obvious against the background of the colossal economic and human loss due to building failure. These losses constitute an enormous economical and societal surcharge. The increasing occurrence and awareness of these incidences have engendered stimulus for studies aiming at abating cases of building failure for sustainable development. This abatement as well as the desire to improve performance of concrete in building and also save associated losses informed the need for evaluation of concrete quality control practices within the study area.

The aim of this research is to evaluate the concrete quality control practices at building sites in North-Eastern Nigeria with a view to improving performance of concrete in building. The specific objectives are to:

- i. Examine the current practices of concrete production on selected building sites in North-Eastern, Nigeria.
- ii. Identify and rank the deficiencies associated with concrete production practices on building sites within the study area.

iii. Determine the adequacy of concreting practice on building sites within the study area.

The issue of non-compliance with quality control standards for non-implementation of quality control measures during construction operations, particularly in areas of structural relevance are leading to problems such as high incidences of building failure, loss of lives, delay in project completion, increase cost of rework and maintenance of buildings etc. which are serious challenges to economic development of Nigeria particularly now that the nation is working towards achieving her vision 20:2020 (Nigeria to become one of the twenty most developed economy in the World by the year 2020).

In view of the increasing building failure most of which were linked to poor performance of concrete in buildings reflect the non-production of quality concrete as a result of bad concreting practices. These indicate failure on part of construction industries and thus require urgent attention to redeem the sector for sustainable development.

Therefore, this paper attempts to contribute to arresting continuous declining of building industry for sustainable development. The study will unveil the concrete quality control practice within the study area and provide trends for stakeholder in building industry for instance building promoter, designer, builder and contractor. The result of this study will guide building promoters in preparing relevant criteria for selection of contractor for building construction. Also designers of concrete structure will find this study beneficial during design process as it will give clue on the areas that will require improvement in design. All the benefit stated above are targeted at enhancing concrete performance in building for sustainable development as it will impact positively towards achieving Nigerian vision 20:2020 and addition to body of knowledge for researchers.

**Research Methodology**

This study covered North-East Geopolitical Zone of Nigeria which includes the six (6) states within the area. They include Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe state. According to [11], the study area lies between Latitude 6° 30'N and 13° 45'N and Longitude 9° 30'E and 14° 45'E, North-Eastern Nigeria. Figure 1 shows the location of the study area. North-East Geopolitical Zone of Nigeria has a tropical climate with variable rainy and dry season. In general the length of the raining season decreases from South to North of the study area with average annual rainfall recorded between 300-1000mm [12]. The temperature and humidity varies relatively within the study area. During the dry season (February – May) the daily temperature range becomes extremely high in the range of 40.0° C and above. The humidity generally is high but it falls during the hot dry Northeast trade wind and the incident solar radiation as recorded by the [12] is between 24 – 28Wm<sup>2</sup>day<sup>-2</sup>.

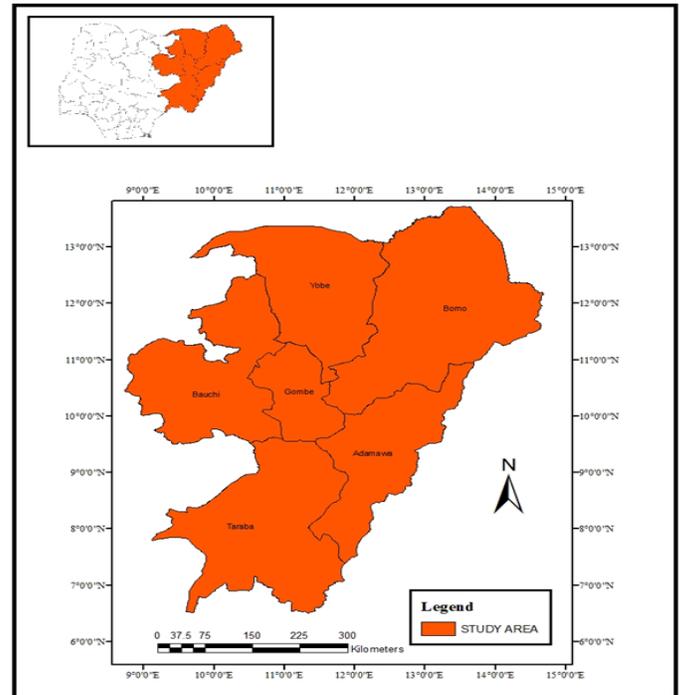


Figure 1. Map of Nigeria Showing North-East Zone (Source: wikipedia.org/wiki/northern region Nigeria)

The questionnaire was developed to provide information for evaluating the production process of concrete from selection of raw materials to curing. It was constructed in three sections to provide information on control of raw material, production process and personnel for concreting. The questionnaire consists of series of both structured and open questions for respondents. .

The items were arranged in categories and sequence/logical order of production process from selection of concrete materials to curing. The checklist was administered by the researcher and that gives him the opportunity of direct observation of the processes involved in the production of in-situ concrete from selected sampled project sites 10 factors were examined in the contract production process in the questionnaire. The process scoring of process of production of concrete and then converted into five point scale using

Survey is a systematic method of gathering information from the target population. Survey approach was adopted for collection of information regarding concrete production on building construction, through the use of questionnaire and evaluative checklist as the instrument. Survey design according to [13] gives a quantitative description of phenomenon such as trends, attitudes, or opinion of population. Based on the results obtained, generalization to the population is possible. Reference [14] stated that survey research is one of the best methods used in collecting data where the objective is to reach a larger portion of the society

which would have been difficult to observe directly or the use of other methods.

Primary and secondary data were used for this study. Primary data was obtained mainly from primary sources which were collected with the use of questionnaire, evaluative checklist and observation, while the secondary data were obtained from related literature to research, articles, journals, published and unpublished thesis and internet.

In this research a total of 100 questionnaires were distributed to elicit responses from Resident Engineer or Concrete production Supervisors working on the investigated project. The total of 62 respondents was achieved which represented 62% of the questionnaires administered. Snowball sampling was adopted as contractors are normally unwilling to disclose amount of projects their handling which might have been difficult to identify project required for this study.

A research population is generally a large collection of individuals or objects that is the main focus of a scientific query and it is for the benefit of the population that researches are undertaken. Therefore, population for this study consisted of all on – going build projects sites with value above 50 million naira and located within the study area. The likert Scale was used to transform some qualitative responses into quantitative data analysis. Thereafter, basic descriptive statistics such as mean, median frequency and percentage were used in the data analysis. As an illustration concrete was classified using the five point scale Table 1.

Table 1. Five-Points scale for Scoring and Classifying the Quality of Concrete

% Quality performance	Class	Score	Remark	Grouping
> 80	A	5	Very Good	Group of Good
60-79	B	4	Good	
40.59	C	3	Fair	Group of Bad
20-39	D	2	Poor	
< 20	E	1	Very poor	

Source: (Filli, 2013)

### Data Presentation and Analysis of Results

The result of Concrete raw materials (cement, fine aggregate, coarse aggregate and water) for the 62 respondents that were surveyed is shown in Tables 2. It gives the performance of each constituent of concrete with mean performance of C. Water and cement constituents got C-class whereas the fine and coarse aggregate component received a D-class mean. The results show that the quality of cement and water used in concrete production at the building sites were in better treatment than the aggregates.

Cement was the part of constituent of concrete that bind the others together. Although there were various types of cement used for production of concrete, only Ordinary Portland Cement (OPC) were observed on the project sites investigated. When the required test on OPC was observed on the investigated project sites, only 25.8% do conduct at least one test. However, there was a low level compliance as regards conducting test to check the quality of cement as indicated in Table 4 and 3. Therefore, this was considered as one of the problems that could seriously affect the quality of concrete.

Sixty four and half percent (64.5%) of the projects investigated used crushed stone as coarse aggregate while 100% of the project used natural sand as fine aggregate. It is shown that only 25.8% and 32.3% of projects investigated conduct at least one test on coarse and fine aggregate respectively. Tables 5 and 6 provide the type of test conducted on coarse and fine aggregate respectively during production of concrete on investigated project. Also the result revealed that some tests were not being conducted on aggregates. The test include aggregate crushing value (ACV) and Losangels abrasion value (LAV).

The water commonly used for production of concrete as observed on most of the projects were fit for drinking. Table 7 indicates 41.9% projects that conduct test. 38.7% of project investigated undertake drinkability test as revealed in Table 8. The criterion of portability of water was not absolute, drinking water may be unsuitable as mixing water when the water has a high concentration of sodium or potassium and there was a danger of alkali – aggregate reaction.

In visual batching, an arbitrary measurement of concrete ingredient was made by eye 61.3% of projects studied employ volume batching while 38.7% do visual batching as indicated in Figure 1 and none of the project investigated do either batching by weight or without measurement.

In figure 2, two (2) methods for mixing concrete was observed in the projects studied. That is mechanical or manual method. 61.30% of the projects investigated adopted mechanical mixing of concrete, while 38.70% employed manual method. All the projects investigated produce their concrete on site and no project use ready mix concrete.

Three (3) methods of compacting concrete were observed during the investigation of the projects this include mechanical, manual and self-compaction of concrete. Figure 2 shows the compaction employed by projects investigated. 45.2% and 29% of the projects adopted mechanical and manual method of compaction respectively while 25.8% are self-compacted (no-compaction). All the projects that adopted mechanical method used internal vibrator i.e. poker vibrator. Also those that employ manual method used hand rodding.

Study revealed that spraying/sprinkling of the concrete was the only method adopted by projects surveyed and with

temperature control measure. The curing period on the investigated projects were observed and 36% of responded cure concrete for at most 2 days and 18% of the projects cure concrete for 12 to 21 days. Figure 3 gives the percentage of projects that adopt curing for a given durations for ordinary Portland cement. 49% of the projects studied were insufficiently cured.

From the result of the surveyed projects temperature control during the concrete production process were not given serious attention. Tables 10, show the performance of the projects investigated for each process and general summary for the processes in terms of temperature control. They project scored 1.98 out of 5 and was graded as D (poor).

Employment of equipment during concrete production processes improves productivity, safety and quality of concrete. Tables 11 show the performance of the projects investigated for each process and general summary for the processes in terms of employment of Equipment.

The research revealed inadequate personnel in terms of knowledge on concrete and effective supervision to guide artisans during concreting as shown in Table 12. Lack of skillful use of concreting equipment was also observed.

The average score and grade of each factor considered on projects investigated was indicated in Table 13 gives the general summary of performance of the projects investigated. Temperature control and personnel got score of 1.92 and 2.11 respectively and the grade was D which implied poor performance. The general performance of the projects examined was (C) and that was fair. It was initially assumed that there is no significant problems with concrete production in building construction site within the study area, however, the result of the research revealed that its adequacy in term of quality cannot be guaranteed based on the procedural operations observed. Table 14 gives simple statistics of the factors and indicated the ranking of the factors considered for the study. Temperature control was the list in performance and ranked no 10, it was the factor that is more severe.

Table 2. Performance of each of the Raw Materials of Constituents of Concrete

Constituents	Number of sites	Score	Mean	Class
Cement	62	170	2.72	C
Fine Aggregates	62	144	2.32	D
Coarse Aggregates	62	150	2.42	D
Water	62	192	3.10	C
Mean Performance of Constituents			2.64	C

Source: Field Survey (2013)

Table 3. Projects that conducted at least one Type of Test on Cement.

Cement Test	Frequency	% Projects
Do not conduct Cement tests	46	74.2
Do conduct Cement tests	16	25.8
Total	62	100

Source: Field Survey (2013).

Table 4. Types of Test Conducted on Cement

Types of test for cement	Number of sites	Frequency	%
Fineness	62	16	25.8
Soundness	62	16	25.8
Compressive Strength	62	0	0
Setting time	62	8	12.9
Chemical analysis	62	2	3.23

Source: Field Survey (2013).

Table 5. Types of Test Conducted on Coarse Aggregates

Types of test for coarse aggregates	Number of sites	frequency	% projects
Sieve analysis	62	14	22.58
Unit weight	62	12	19.35
Specific gravity	62	10	16.13
Water absorption	62	2	0.30
Aggregate Crushing Value(ACV)	62	0	0
Losangeles Abrasion Value(LAV)	62	0	0
Flakiness Index	62	0	0
Soundness	62	0	0
Clay lump and friable particles	62	0	0
Dust content	62	12	19.35

Source: Field Survey (2013).

Table 6. Types of Test Conducted on Fine Aggregates

Types of test for fine aggregates	Number of sites	Frequency	% projects
Sieve analysis	62	20	32.26
Unit weight	62	20	32.26
Specific gravity	62	16	25.81
Water absorption	62	14	22.58
Fineness test	62	4	6.45
Chloride test	62	4	6.45
Silt and clay amount	62	0	0
Organic impurity	62	0	0

Source: Field Survey (2013).

Table 7. Water Tests by Projects Investigated

Water Test	Number of sites	Frequency	% Project
Do conduct water test	62	26	41.9
Do not conduct water test	62	36	58.1
Total	62	62	100

Source: Field Survey (2013).

Table 8. Water Tests carried out by Projects Investigated

Water test	Number of sites	Frequency	% projects
Drinkability test only	62	24	38.7
Other water test	62	2	3.23
Do not conduct water test	62	36	58.10
Total	62	62	100

Source: Field Survey (2013).

Table 9. Temperature Control Performance during Concreting Processes

Processes	Number of sites	Score	Mean	Class
Mixing	62	144	1.84	D
Transport	62	158	2.55	C
Placement	62	94	1.5	D
Curing	62	126	2.03	C
Mean Performance			1.98	D

Source: Field Survey (2013).

Table 10. Use of Equipment during Concrete Production

Processes	Number of sites	Score	Mean	Class
Batching	62	162	2.60	C
Mixing	62	160	2.58	C
Transport	62	172	2.77	C
Placement	62	158	2.45	C
Compaction	62	164	2.65	C
Curing	62	158	2.55	C
Mean Performance			2.60	C

Source: Field Survey (2013).

Table 11. Concrete Production Personnel

Personnel	Number of sites	Score	Mean	Class
Knowledge of concrete	62	142	2.29	D
Quality Control Plan	62	102	1.65	D
Mean Performance			1.97	D

Source: Field Survey (2013).

Table 12. Summary of Performance of Projects at Various Stages of Concrete Production

Processes	Number of sites	Score	Mean	Class
Raw Materials	62	160	2.58	C
Batching	62	212	3.42	C
Mixing	62	196	3.16	C
Transport	62	205	3.31	C
Placement	62	199	3.21	C
Compaction	62	216	3.48	C
Curing	62	160	2.58	C
Temp. Control	62	120	1.94	D
Equipment	62	161	2.60	C
Personnel	62	131	2.11	D
Mean Performance			3	C

Source: Field Survey (2013).

Table 13: Ranking of Project Performance at Various Stages of Concrete Production

Variable	N	Mean	Std dev	Sum	Min	Max	Ranking
Raw materials	62	2.61290	0.79661	162.00	1.00	4.00	7
Batching	62	3.45161	0.66966	214.00	2.00	4.00	2
Mixing	62	3.19355	1.06876	198.00	2.00	5.00	5
Transport	62	3.35484	0.90711	208.00	2.00	5.00	3
Placement	62	3.25806	0.67594	202.00	2.00	5.00	4
Compaction	62	3.61290	1.22464	218.00	2.00	5.00	1
Curing	62	2.61290	0.70953	162.00	2.00	4.00	7
Temp-Control	62	1.96774	1.07074	122.00	1.00	4.00	10
Equipment	62	2.64516	1.07271	164.00	1.00	4.00	6
Personnel	62	2.12903	1.16624	132.00	1.00	4.00	9

Source: Field Survey (2013).

Table 14: Duncan's Multiple Range Test for the Two Groups (Good and Bad)

Adequacy Groups	Mean
Bad (C, D and E)	44.40 <sup>a</sup>
Good (A and B)	17.40 <sup>b</sup>

a and b are Duncan grouping.

Source: Field Survey (2013).

Table 15: Duncan's Multiple Range Test for Performance (Scores)

Score	Class	Mean
5	A	4.40 <sup>c</sup>
4	B	13.00 <sup>abc</sup>
3	C	22.20 <sup>a</sup>
2	D	15.40 <sup>ab</sup>
1	E	6.80 <sup>bc</sup>

a, b and c are Duncan grouping.

Source: Field Survey (2013).

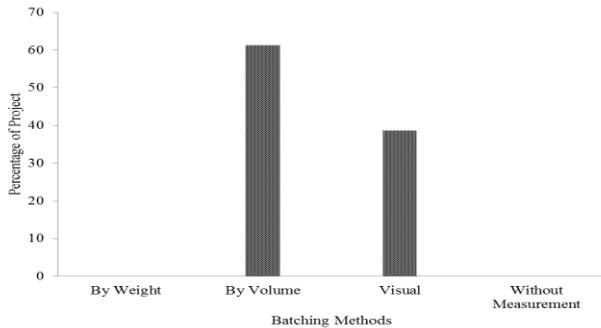


Figure 1. Type Batching Methods for Concrete Material

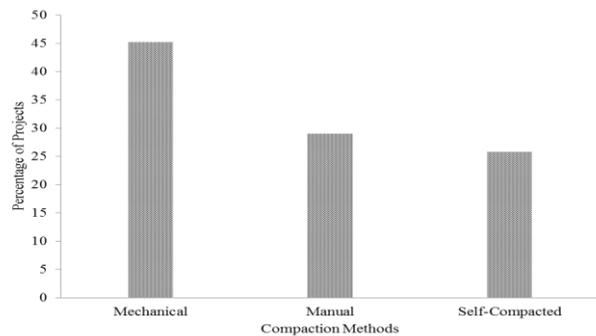


Figure 2. Compaction Methods during Concrete Production

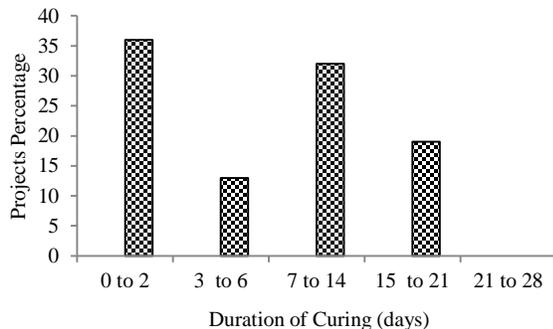


Figure 3. Duration of Curing Concrete

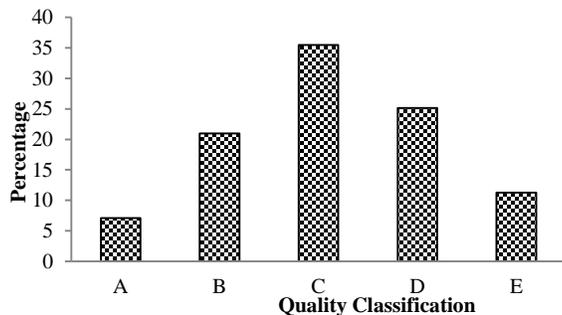


Figure 5. Classification of Concrete Quality on Investigated Project

## Conclusion

This paper attempted the evaluation of concrete quality production within North Eastern Nigeria with a view to ascertaining the current production practices. During the course of the study related literature on the quality of concrete and the production process were reviewed and the implication of the current practices on the adequacy of concrete was drawn. Different tools were used for data collection, ranging from the checklist, questionnaires, observation and interview of the concreting workers on the project site. In order to translate the data collected into a meaningful interpretation, the use of analysis of variance was employed along with descriptive statistics. It was found out that the quality of concrete within the study area was inadequate as the average score of performance in terms of quality is 3 (C) and also confirmed by Duncan's Multiple Range Test for the two groups (adequate and inadequate).

Based on the research conducted within the study area, the quality of concrete being produced cannot be guaranteed owing to improper practices on sites. The field survey indicated low performance from the score of quality control parameters identified and therefore the concrete was said to be inadequate for usage. The result of the research confirmed previous studies which indicated that concrete quality were unsatisfactory and unfavorable in Nigeria due to improper concrete production process and methods as revealed by this research. Therefore, this type of concrete with inadequate quality were unsafe and may fail during usage as identified by NBRRI (2012) that poor concreting as major course of collapse of building in Nigeria.

In light of result of the study the following recommendations will enhance concreting practice within the study area.

- i. Need for quality control personnel and plan for concreting works.
- ii. Constructors and concrete suppliers to ensure adequate personnel in terms of knowledge and skillfulness as regards concrete and its production.
- iii. Constructors and concrete suppliers to ensure use of proper materials and procedure for production of concrete.

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